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Semiconductor devices – Micro-electromechanical devices – Part 16: Test methods for determining residual stresses of MEMS films – Wafer curvature and cantilever beam deflection methods

Dispositifs à semiconducteurs – Dispositifs microélectromécaniques – Partie 16: Méthodes d'essai pour déterminer les contraintes résiduelles des films de MEMS – Méthodes de la courbure de la plaquette et de déviation de poutre en porte-à-faux

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SEMICONDUCTOR DEVICES – MICRO-ELECTROMECHANICAL DEVICES –

Part 16: Test methods for determining residual stresses of MEMS films – Wafer curvature and cantilever beam deflection methods

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The text of this standard is based on the following documents:

FDIS	Report on voting
47F/209/FDIS	47F/214/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

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SEMICONDUCTOR DEVICES – MICRO-ELECTROMECHANICAL DEVICES –

Part 16: Test methods for determining residual stresses of MEMS films – Wafer curvature and cantilever beam deflection methods

1 Scope

This part of IEC 62047 specifies the test methods to measure the residual stresses of films with thickness in the range of 0,01 μm to 10 μm in MEMS structures fabricated by wafer curvature or cantilever beam deflection methods. The films should be deposited onto a substrate of known mechanical properties of Young's modulus and Poisson's ratio. These methods are used to determine the residual stresses within thin films deposited on substrate [1][1].

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62047-21, *Semiconductor devices – Micro-electromechanical devices – Part 21: Test method for Poisson's ratio of thin film MEMS materials*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
residual stress
σ_f
stress that remains after the original cause of the stresses (external forces, heat source) has been removed

3.2
curvature
κ
amount by which a geometric object deviates from being flat

Note 1 to entry: In case of a circle, $\kappa = 1/R$ where R is the radius.

3.3
body
object with mass, not only energy, that is three dimensional (extended in 3-dimensions of space), has a trajectory of position and orientation in space, and is lasting for some duration of time

[1] Numbers in square brackets refer to the Bibliography.

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4 Testing methods

4.1 General

The deposition of a film shall make the bi-layer structure to bend together due to residual stresses in the film. The amount of deflection is directly related to the residual stresses of the film.

There are two kinds of test methods such as wafer curvature method and cantilever beam deflection method in order to measure the residual stress.

In the case of tensile residual stress, the substrate bonded to the film becomes concave, whereas for a compressive residual stress, it becomes convex.

4.2 Wafer curvature method

4.2.1 General

Wafer curvature method should be used in a wafer level processing. A wafer should be biaxial symmetric and stress free.

Stoney [2] used a bi-layer plate system composed of a stress bearing thin film, of uniform thickness h_f, deposited on a relatively thick substrate, of uniform thickness h_s, and derived a simple Equation (1), so-called Stoney's equation, relating the curvature, κ, of the system as shown in Figure 1, to the stress, σ_f of the film as follows [3]:

$$\sigma_f = \frac{E_S h_s^2 \kappa}{6(1-\nu_s)h_f} \tag{1}$$

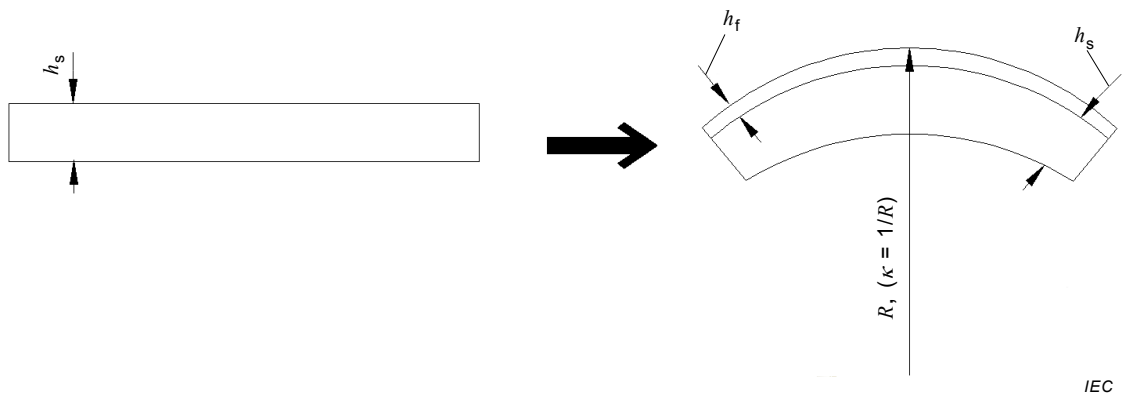
where

f and s are film and substrate, respectively;

E is the Young's modulus;

ν is Poisson's ratio (see IEC 62047-21)

The formula has been extensively used in the literature to infer film stress changes from experimental measurement of system curvature changes [4].



a) Substrate before depositing thin film **b) After depositing thin film on substrate**

Figure 1 – Schematic drawing of compressive residual stress induced curvature after depositing thin film on substrate

The following assumptions should be satisfied in order to use Equation (1) [3]:

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